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(71) Applicant: **GAMBRO AB**
Post Box 10101
S-220 10 Lund(SE)

(72) Inventor: **Sternby, Jan Peter**
Sparsnögatan 45
S-226 52 Lund(SE)

(74) Representative: **Boberg, Nils Gunnar Erik**
Gambro AB Patent Department Box 10101
S-220 10 Lund (SE)

(54) Dialysis system.

(57) A method for determining a blood parameter in the extra-corporeal blood circuit of an artificial kidney comprising a dialyzer (37) having a semipermeable membrane delimiting two compartments for the circulation of blood and a dialysis liquid on either side of the membrane.

The method is characterized by the steps of:

- Circulating in the dialyzer at least a dialysis liquid,
- Measuring in the dialysis liquid at least two values of the parameter, respectively upstream and downstream from the dialyzer, and
- Calculating from the measure values of the parameter in the dialysis fluid, the value of the corresponding blood parameter.

A method for determining an actual dialysance of an artificial kidney is also described comprising a dialyzer having a semipermeable membrane delimiting two compartments for the circulation of blood and a dialysis liquid on either side of the membrane.

Said method is characterized by the steps of :

- Circulating successively in the dialyzer a first and a second dialysis liquid having different concentration in a substance.
- Measuring in the first and second dialysis liquids, the concentration of the substance upstream and downstream from the dialyzer.
- Calculating from the measured concentrations of the substance in the first and second dialysis liquid, the concentration of the substance in the blood at the inlet of the dialyzer, and
- Calculating the dialysance of the artificial kidney from the calculated and measured concentrations of the substance.

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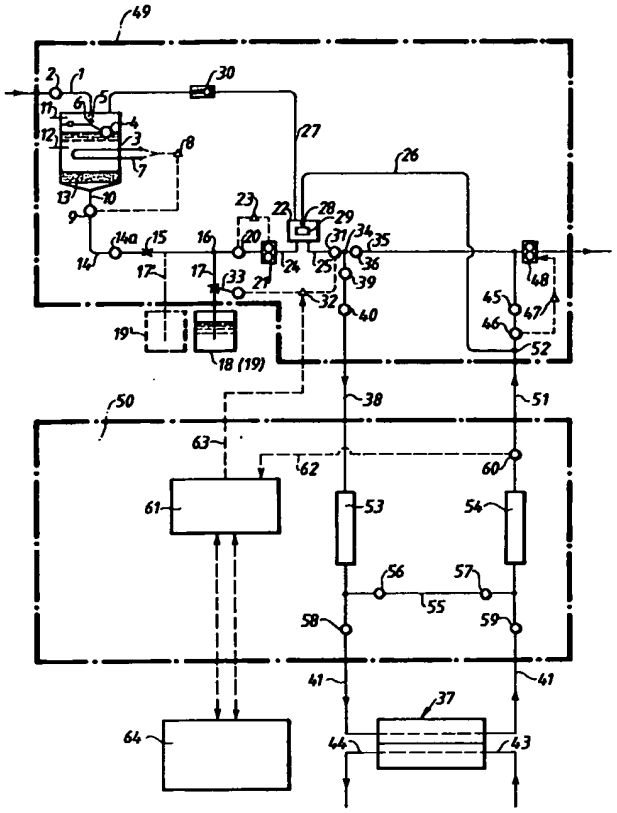
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TECHNICAL FIELD

The following invention relates to a dialysis system, comprising means for the conducting of blood and dialysis liquid respectively on either side of one or more membranes in a dialyser, means for the control of one or more parameters of the dialysis liquid before the dialyser and means for measuring at least one parameter of the dialysis liquid after the dialyser.

The term dialysis system here also comprises systems for similar treatments, e g haemodiafiltration, that is to say dialysis with such high ultrafiltration, that certain quantity of replacement liquid has to be supplied to the patient to make up for the filtrate removed.

BACKGROUND ART

In a normal dialysis treatment there is normally no feedback of patient's data to the dialysis machine. Thus the patient's temperature, blood values etc may be no matter how abnormal without the machine reacting, as long as the machine's own values are correct.

As an example of systems which control the composition of the dialysis liquid irrespectively of the blood parameters of the individual patient can be mentioned, for example, those described in the US patents 4 158 034, 4 293 409 and 4 508 622.

The system in accordance with the invention may be said also to constitute a further development of the dialysis system developed by the Gambro Group which is marketed under the name of Gambro AK-10 and Gambro AK-100. Details of this system are described more fully, for example, in the two first mentioned US patents and in the US patents 4 194 974, 4 191 359, 4 585 552 and 4 536 201 and the European patent publications EP B 22 922, EP A 204 260, EP A 204 174, EP A 208 090 and EP A 238 809.

DISCLOSURE OF INVENTION

It is an object of the present invention to increase the patient's comfort by making the treatment more individualized. This can be done in that certain patient's parameters are measured and adapted to control the dialysis machine used. Examples of such patient's parameters may be blood pressure, temperature, blood gas content, electrolyte content, pH-status etc. Such measurements should be made wholly without blood contact, so that transmitters etc need not be of the disposable type or be sterilized between each treatment.

The dialysis system in accordance with the invention is characterized in the first place by means for a comparison of the parameter measured after the dialyser with the set value of the corresponding parameter before the dialyser. Through such a comparison a measure of the dialysis performed is obtained, and with the help of this measure, and knowledge of other, e g adjusted values relevant for the analysis, conditions on the blood side can be determined theoretically and thereby controlled.

The comparative value measured can be used simply for a control of the composition of the dialysis liquid an thereby an indirect passive control of the composition of the blood. Preferably though the dialysis sytems in accordance with the invention is provided instead with means for using the result measured for the calculation of a blood parameter which is altered as a function of the parameter measured, for the purpose of calculation and/or control of this blood parameter in the patient.

Inasfar as the electrolyte composition of the blood is concerned, it has been found that it is a prerequisite to obtain a value of this by measuring the conductivity of the dialysis liquid which passes the dialyser. Through the influence of the blood the conductivity of the incoming dialysis liquid will be altered and the magnitude of the alteration will depend on the composition of the blood. Since the conductivity for the most part is produced by sodium ions together with its anions, the conductivity largely becomes a measure of the sodium content in the dialysis liquid and in the blood. Preferably, therefore, the dialysis system in accordance with the invention is provided with a conductivity meter arranged after the dialyser for measuring the conductivity in the dialysis liquid for the purpose of calculation and/or control of the conductivity and/or the sodium content in the blood.

Alternatively the dialysis system in accordance with the invention can be provided with one or more ion-selective electrodes for measuring the content of one or more defined ions in the dialysis liquid for the purpose of calculation and/or control of the corresponding ion content in the blood. In this way other ions beside sodium can also be measured, such as for example calcium and potassium.

It will be obvious to those versed in the art, that many other blood parameters too can be calculated and/or controlled with the help of corresponding values measured on the dialysis liquid side. Thus it should be possible, for example, to provide the dialysis system in accordance with the invention with a gas analyser arranged after the dialyser for measuring the gas content in the dialysis liquid for the purpose of calculation and/or control of corresponding blood gases. However, this has not yet been verified in practice.

It will be obvious, moreover, to those versed in the art that it would be better to measure directly various ions with the help of ion-selective transmitters instead of taking the route via a conductivity meter. With the technique available today, however, a conductivity measurement is appreciably more stable, more accurate, simpler and less expensive. Preferably, therefore, just one conductivity meter is used. It is intended then with the help of this to measure the conductivity on the dialysis liquid side so a to calculate thereafter theoretically the conductivity on the blood side. On the assumption that the conductivity largely depends upon the sodium content, the sodium passage or sodium dialysance will be determining for the effect of the blood side on the conductivity value of the dialysis liquid measured after the dialyser. A simple mass balance for sodium at constant flow and assuming the so-called Donnan effect, furnishes the formula:

$$Cdout = Cdin + (Cbin - Cdin) \times K$$

wherein
Cdout = the conductivity or the concentration of sodium in used dialysis liquid.
Cdin = the conductivity or the concentration of sodium in fresh dialysis liquid.
Cbin = the conductivity or the concentration of sodium in untreated blood.
K = proportionality constant depending on the flow.
If the ultrafiltration is kept at zero, K becomes D1/Qd (=relative dialysance) where
D1 = dialysance value for sodium/conductivity.
Qd = dialysis liquid flow.
The same formula applies also where the ultrafiltration is different from zero, but with a modified value of K.

When the factor K is known, and by measuring Cdout, it is possible to calculate Cbin, if at the same time Cdin is put to equal the set value of the corresponding matter.

The factor K can be determined in two different ways. The simplest is, starting out from a knowledge of dialyser, blood flow and liquid flow, to determine it empirically. It is also possible to determine K continuously by a regular change of the set conductivity of the liquid. At each change a measure of K is obtained from a comparison between the conductivity measured before and after the dialyser respectively. This method requires a liquid conductivity which during the treatment is altered by steps, e g every 6th minute by 0.5 mS/cm, up or down respectively from the set value, which ought to be in the order of magnitude 13.7 - 14.0 mS/cm. These changes are so rapid, that the body quite likely would not keep up with them to any appreciable extent. At the same time they are so small that they do not notably affect the aforementioned formula.

The dialysis system in accordance with the invention appropriately is provided with means for the control of the composition of the dialysis liquid before the dialyser as a function of the parameter measured in such a manner that the dialysis result becomes a direct function of the corresponding blood parameter. As a result, conditions on the blood side will be directly determining for the dialysis and not the preset values on the dialysis liquid side, as has been the case normally up to now. If the dialysis system in accordance with the invention is adapted for determination of the conductivity and/or the sodium content in the blood, the said means for adjusting of the composition of the dialysis liquid before the dialyser may be adapted to bring about an equilibrium between the conductivities in the dialysis liquid and in the blood. In this manner a conductivity adapted to the individual is obtained, which should provide maximum comfort for the patient.

The dialysis system in accordance with the invention may comprise, in a manner known it itself, means for measuring the actual dialysis liquid parameter, which is measured after the dialyser, also just before the same. The system suitably is provided also with a shunt line for conducting the fresh dialysis liquid past the dialyser directly to the measuring device normally placed after the dialyser, for the purpose of calibration of the measuring devices used. It should be noted in this connection that any minor fault common to both measuring devices is of less importance for the final result than if only one of the measuring devices were to present an incorrect measuring value.

The dialysis system in accordance with the invention, in a manner known in itself, may comprise means for the measuring of the said parameter of the dialysis liquid both before and after the dialyser. In such case the parameter measured after the dialyser instead may be compared with the value of the same parameter measured before the dialyser. In practice it has been found simpler, however, to use a corresponding set value for comparison. This set value, of course, has already been entered into the system.

BRIEF DESCRIPTION OF DRAWINGS

The invention is described in more detail in the following with reference to the attached drawing which shows a block diagram comprising a mixing module, a flow control module, an external computer and a dialyser.

BEST MODE OF CARRYING OUT THE INVENTION

On the drawing an inlet duct for fresh water is designated 1. This duct 1, which is provided with an inlet valve 2, leads to a water vessel 3. This vessel 3 is provided with a float valve 4 which is adapted to close the water intake with the help of a closing cone 6 when the water vessel has been filled. The water vessel, moreover, comprises means 7 for the heating of the water, e g in the form of a heating loop. This heating loop is controlled by a temperature regulating means 8 which in turn is controlled by a temperature transmitter 9 in the outlet duct 10 from the vessel 3. Furthermore the vessel 3 comprises maximum and minimum monitors 11 and 12 respectively, shown schematically, for sensing the liquid level in the vessel. These level monitors may be adapted, for example, to control directly the inlet valve 2. Finally the vessel contains a filter element 13, shown chematically, which in the first place is intended to remove any solid particles from the water, but which in practice also removes a certain amount of gas, e g free gas bubbles.

After heating the fresh water supplied is conducted via the outlet line 10, the temperature transmitter 9, a duct 14 with a shut-off valve 14a, and a throttle valve 15 to a branching point 16. Here a branch 17 is connected which normally starts out from a source 18 of salt solution concentrate. Generally this source quite simply consists of a drum with a salt solution. When the system shown is to be sterilized, however, this drum is replaced by one containing a sterilizing agent which is marked (19) in the figure. In practice this is the simplest solution. It would also be possible of course, would this be required for any special reason, to connect a further line 17' to the system parallel with the line 17 for the connection of a separate vessel 19'. This has been indicated in the figure by broken lines.

From the point 16 the liquid flows via pressure gauge 20 and a pump 21 to a bubble separator 22. The pressure gauge 20 here controls the pump via a pressure regulating means 23. The supply line to the bubble separator 22 has been designated 24.

From the bubble separator 22 starts out beside the ordinary line 25, also a line 26 for the removal of the separated gas, and also a return line 27. The inlet 28 to the line 26 is controlled by a float valve 29 which closes this inlet when the bubble separator 22 is filled with liquid in connection with sterilization. The return line 27 is provided with a spring-loaded check valve 30 and leads back to the liquid vessel 3.

The line 25 leads to a conductivity meter 31 which via a control means 32 controls a throttle valve 33 in the line 17 for salt solution concentrate. Alternatively it may control instead a concentrate pump in the same line 17. After the conductivity meter 31 the liquid flow reaches a new branching point 34 from which originates shunt line 35 with a valve 36. This shunt line 35 is used when it is desired to couple the liquid flow past the dialyser, e g when an abnormality is detected in the dialysis liquid, for example, of its temperature or salt content. Normally the liquid otherwise flows to the dialyser 37 via a line 38 which contains a valve 39 and a flow meter 40. On its way to the dialyse 37 the dialysis liquid passes a flow control module which, as a whole, is designated 50. The components described up to now, on the other hand, are included in a liquid preparation module which, as a whole, is designated 49. On its way from the dialyser 37 the dialysis liquid once agains passes the flow control module 50 to be returned via a line 51 to the module 49. At a point 52 the line 51 is coupled together with the line 26 from the bubble separator 22.

The lines or tubings which are normally coupled to the dialyser 37 are designated 41. During sterilization, though, these tubings are coupled to a "safety-bypass", not shown in the drawing. An example of such a "safety-bypass" is described in the US patent 4 122 010 and it need not be described in greater detail, therefore, in connection with the present invention. The inlet and outlet respectively on the blood side of the dialyser are designated 43 and 44.

A blood detector 45 provided in the module 49 raises an alarm which possibly shuts down the whole system if blood is detected in the dialysis liquid. This blood detector, for example, may be a transparent tubing opposite an otherwise shielded photocell device which directly senses the occurrence of any blood in the dialysis liquid. Before the blood detector a pressure gauge 46 is passed which via a control means 47 controls a liquid pump 48. Thereafter the liquid flow is conducted finally to a drain, not shown.

In the module 50 the dialysis liquid flow to the dialyser is measured in a first measuring device 53. In the same manner the dialysis liquid flow from the dialyser is measured in a second measuring device 54. Through a comparison of the values obtained the ultrafiltration in the dialyser can be determined. The two measuring devices 53 and 54 may be included, for example, in a differential measuring arrangement of the type which is described in British patent 2 003 274 or in the US patent 4 585 552. During the calibration of the measuring devices the dialyser is shunted with the help of a bypass line 55 comprising two valves 56 and 57. At the same time the lines to and from the dialyser are shut off with the help of valves 58 and 59 respectively.

After the dialysis liquid flow has passed the measuring device 54 it passes a device 60 for the measurement of at least one parameter representative for it. In the example shown this device consists of a conductivity meter. The value measured is passed to a microprocessor 61, which is indicated by the broken line 62. Here the measured value is compared with the set value of the same parameter before the dialyser, that is to say in this case the conductivity. This set value is adjusted with the help of the microprocessor 61 which is indicated by the broken line 63. This takes place thus with the help of the afore-mentioned control means 32. If desired the microprocessor 61 may be provided furthermore with data from or it may furnish data to a further personal computer 64. With the help of this further computer, for example, the individual values of the patient can be transferred to the microprocessor 61 at the same time as the values calculated for the blood side of the dialyser can be noted.

Naturally the invention is not limited solely to the embodiment described above but can be varied within the frame-work of the subsequent claims. For example, the system in accordance with the example of an application described above is based on only one concentrate, that is to say that taken from the container 18. The invention also may be applied, however, e g when two concentrates are used in the manner which is described in EP-B1-22922. The value measured in the device 60 is compared in such a case with the ready-mixed dialysis liquid, that is to say after mixing in of the two concentrates used. The two concentates, for the rest, need not be in liquid form. Concentrate in powder form may also be used e g in accordance with what is described in European patent EP-B-278 100.

Claims

1. A method for determining a blood parameter in the extracorporeal blood circuit of an artificial kidney comprising a dialyzer having a semipermeable membrane delimiting two compartments for the circulation of blood and a dialysis liquid on either side of the membrane, **characterized** by the steps of:
   - Circulating in the dialyzer at least a dialysis liquid,
   - Measuring in the dialysis liquid at least two values of the parameter, respectively upstream and downstream from the dialyzer, and
   - Calculating from the measure values of the parameter in the dialysis fluid, the value of the corresponding blood parameter.

2. A method according to claim 1, wherein the blood parameter is the concentration of a substance, **characterized** by the steps of:
   - Circulating successively in the dialyzer a first and a second dialysis liquid having different concentration in the substance,
   - Measuring in the first and second dialysis liquids, the concentration of the substance upstream and downstream from the dialyzer, and
   - Calculating from the measured concentrations of the substance in the first and second dialysis liquid, the concentration of the substance in the blood at the inlet of the dialyzer.

3. A method according to claim 2, **characterized** in that the concentration of the substance in blood is calculated according to the formula:

   $$CD_{out} = CD_{in} + (Cb_{in} - Cd_{in}) \times D/Qd$$

   wherein
   Cd_{in} = concentration of the substance in the dialysis liquid upstream from the dialyzer.
   Cd_{out} = concentration of the substance in the dialysis liquid downstream from the dialyzer.
   Cb_{in} = concentration of the substance in the blood upstream from the dialyzer.
   D = dialysance of the artificial kidney for the substance.
   $\overline{Q}$ = flow rate of the dialysis liquid.

4. A method according to any of the preceding claims, **wherein** the substance is sodium.

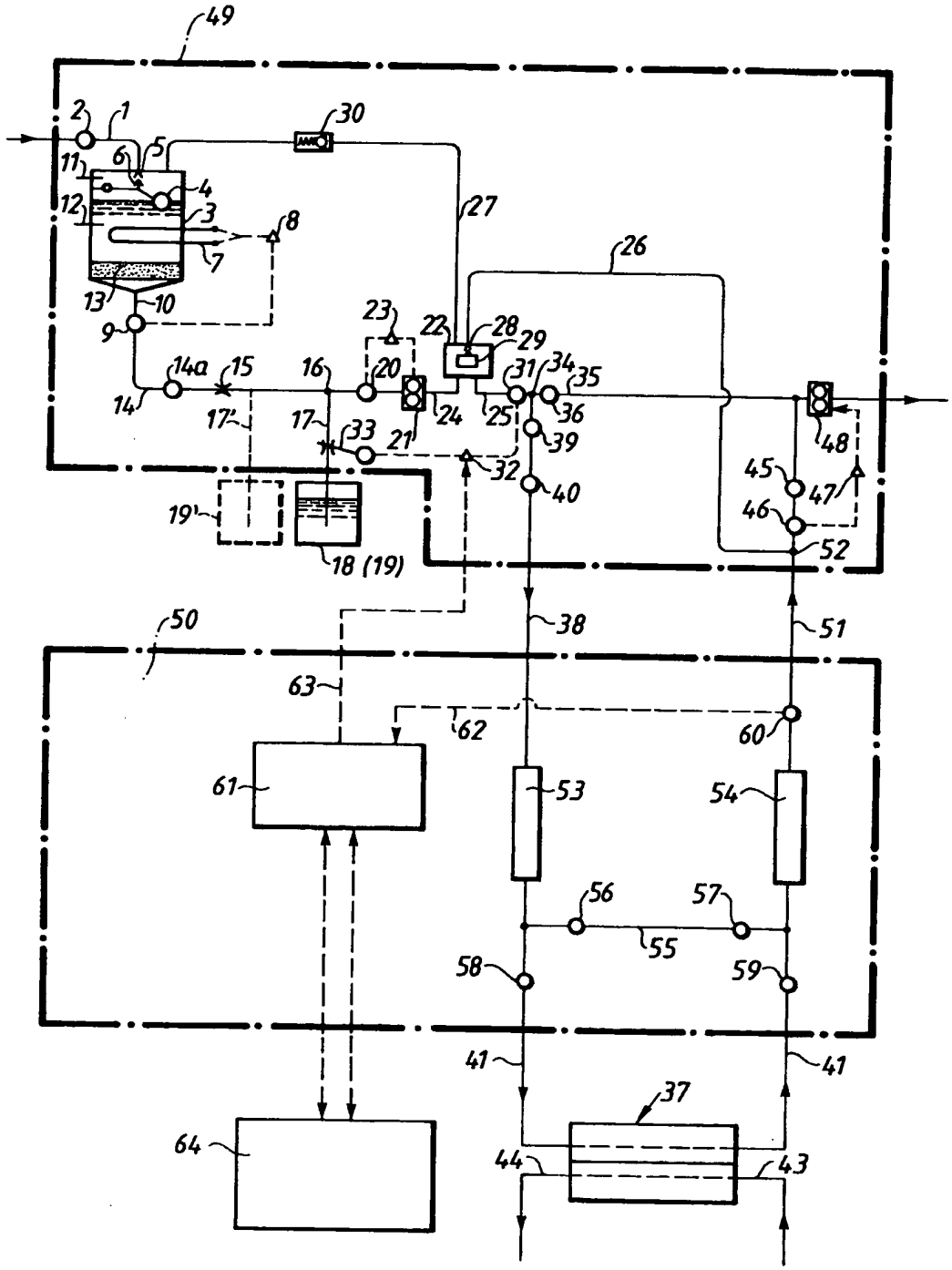
5. A method for determining an actual dialysance of an artificial kideny comprising a dialyzer having a semipermeable membrane delimiting two compartments for the circulation of blood and a dialysis liquid on either side of the membrane **characterized** by the steps of:
   - Circulating successively in the dialyzer a first and a second dialysis liquid having different concentration in a substance.
   - Measuring in the first and second dialysis liquids, the concentration of the substance upstream and downstream from the dialyzer.
   - Calculating from the measured concentrations of the substance in the first and second dialysis liquid, the concentration of the substance in the blood at the inlet of the dialyzer, and
   - Calculating the dialysance of the artificial kidney from the calculated and measured concentrations of the substance.

6. A method according to claim 5, **characterized** in that the concentration of the substance in the blood and the dialy-sance for the substance are calculated according to the following formula:

Cd out = Cd in + (Cb in - Cd in) x D/Qd

wherein
Cd in = concentration of the substance in the dialysis is liquid upstream from the dialyzer.
Cd out = concentration of the substance in the dialysis liquid downstream from the dialyzer.
Cb in = concentration of the substance in the blood upstream from the dialyzer.
D = dialysance of the artificial kidney for the substance.
Q = flow rate of the dialysis liquid.

7. A modification of a method according to any of the claims 1-6, **characterized** in that the measured value Cd in is replaced by the corresponding set value.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EUROPEAN SEARCH REPORT

Application Number

EP 93 10 0634

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	EP-A-0 097 366 (FRESENIUS AG) * page 5, line 4 - page 8, line 17; claims 1,2,4,5; figure 1 *	1-7	A61M1/14 A61M1/34
Y	WO-A-8 600 239 (VEECH) * claim 18; figure 6 *	1-7	
A	SARGENT, J.A. , GOTCH, F.A. " Principles and Biophysics of Dialysis " in: " REPLACEMENT OF RENAL FUNCTION BY DIALYSIS " , page 53 - 96 A W.DRUKKER, F.M. PARSONS, J.F. MAHLER (EDITORS), NIJHOFF PUBLISHER, DEN HAAG, 1983 * page 57, paragraph 4 - page 60, paragraph 1 *	1-7	
A	DE-A-2 825 134 (CORDIS DOW CORPORATION) * page 27, line 11 - page 30, line 12 * * page 32, line 17 - page 33, line 28; claims 1-7; figures 4-6 *	1-7	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4) A61M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	22 MARCH 1993	MICHELS N.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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